NOTE ON SOME OF THE PHYSICAL FACTORS AFFECTING REACTION TIME, TOGETHER WITH A DESCRIPTION OF A NEW REACTION KEY

By Frank Angell

The history of reaction-time investigations discloses a curious combination of painstaking accuracy in regard to the functioning of the time-measuring apparatus together with a more or less happy-go-lucky arrangement at the other end of the experiment.

Thus the chronoscope and its standardizing instruments have been the subjects of minute and laborious investigation, whilst the reagent, after assuming his 'convenient and comfortable position' has usually been left to his own devices in carrying out the reaction prescriptions. Whether however the reagent obeyed the directions, whether, for example, wrist and forearm movements did not enter into play where finger movements were prescribed, are matters which the experimenter has rarely been in a position to determine. Indeed it has only been of comparatively recent date that investigation has been directed to the initial pressure, the "antagonistic motion" of the break reaction.

Among other neglected factors in these experiments has been the effect of the tension of the reaction key spring. This has usually been set at a 'comfortable and convenient' resistance, and variations within these 'comfortable and convenient' limits have been regarded as negligible. This may be the case, but it is a minor question quite as well worth investigating as a variation of 2 or 3 sigma in the readings of the chronoscope.

The question was taken up as a "minor study" by two students in the advanced course in psychology— Miss Lanktree and Miss Morrison. The lever arm of a Morse key was set at tensions of 10, 20, 50, 100, and 200 grams respectively, and for each tension 10 series of 10 reactions each were taken. The first of these series does not enter into the averages given in Table I as the fall-hammer showed irregularities in the chronoscope at the time this series was taken. Each day the 5 series were run through twice—the second time reversing the order of the first, the order of the several series changing from day to day. The 15 volt current was furnished by a mercury rectifier and maintained at the same strength for

each day, usually at 0.47 amp. The mean variation of the hammer readings ran from one to three sigma—not very accurate but sufficiently so for the purposes of the experiment.[1] The stimulus came from a sound-hammer placed behind the reagent, who occupied a room adjacent to that of the experimenter. The reagents noted the condition of attention as good, moderate or strained (the last referring to the accompanying muscular tension) and in addition marked the reaction as sensory or muscular. Almost all of the reactions were characterized as sensory;—seemingly from strain sensations in the ear adapting it to the direction of the stimulus. L. had already been reagent in another investigation for more than a semester and both had been experimenting on reaction time in the second year's course of laboratory work.

Table I gives the results of the experimentation for the several tensions of the reaction key. It shows noticeable differences for all tensions in case of L. and a noticeable difference between the tension of 200 grams and the remainder of the series for M.

TABLE I

Reaction times for different tensions of spring of telegraph key. Reagents L. and M.

	L		M	
Tension Grams	r. t.	m. v.	r. t.	m. v.
10	129.8	8.0	136.9	8.6
20	127.3	7.5	136.1	6.6
50	122.4	4.9	135.2	9.1
100	120.8	7.7	135.1	10.9
200	116.0	4.7	127.0	7.9

The introspections do not indicate any marked change in the attitude of the reagents for the stronger pressures of the key. Once M. notes a strain in the hand with 200 grams, but the reaction itself is noted as sensory, *i. e.*, the sensory content of consciousness at the moment of reaction was strain sensations in the head or ears directed toward the source of sound. The increase in tension, therefore, would not seem to result for the reagent in a direction of attention to the hand and a change to the muscular form of reaction. L. asserted that there

[1]It is, perhaps, worth while to note that the chronoscope "neuerer Construction" used in this investigation, with only 4 years of use is a much less steady instrument than our old chronoscope; also "neuerer Construction" which has weathered 20 years of general laboratory service.

was no noticeable difference to her in the set of the hand for the 10, 20 and 50 grams of pressure, but that the transition from any of these to 100 grams and from 100 to 200 was marked. Nevertheless L's reactions show a steady decrease in quickness from 10 to 200 grams. The shortening of the reaction time with increase in tension of the key spring is, therefore, probably physical and due to an acceleration of the motion of the reacting finger imparted by the recoil of the spring. The tension at which the acceleration would be noticeable would depend on the manner of reaction: ten grams pressure might accelerate a finger reaction but not one from the wrist or elbow. As a result of long practice, L. had become skilled in the finger reaction. This is possibly the reason why, for this reagent, the effects of each tension were noticeable. A measurement of the rapidity of the free recoil of the spring for 10 grams of tension showed that a separation of the contacts of $\frac{1}{5}$ of a millimeter—more than sufficient to break the current—took place in 0.0005 sec. which of course is considerable faster than the reacting finger can move at the beginning of its course. This is to answer the possible objection that for the weaker tensions, the reacting finger moved up faster than the key-bar.

Part 2. Experiments with Trigger Reaction Key.

As is the case with much of its apparatus, experimental psychology found the ordinary telegraph key already in use and adopted it for its own purposes. The key is very convenient in manipulation and the motion it calls for is 'natural.' Serious objections to it are the antagonistic motion with the break reaction and variability of extent of the reaction motion. Another easy and natural motion is that of the finger in pulling a trigger, with the advantage of a very slight tendency, if any, towards the opposed reaction, though it may well permit an anticipatory contraction. The experiments presently to be described were carried out with a new key of the trigger type.

The elimination of the antagonistic reaction would, in itself, hardly be a sufficient reason for adding another instrument to the already long list of reaction keys. This trigger key, however, measures the force and extent of the reaction movement as well as its time. As is evident from the accompanying figure, the key is simple in construction. A cylindrical, self-registering spring balance is mounted horizontally. The movable end is provided with a ring for the reacting finger and in front of this stands an adjustable post serving as a brace for the hand. Electrical contact is made through the horizontal adjustable rod R. mounted parallel to the cylinder. This rod is connected with the binding-screw S^{11} the other binding post S^{12}

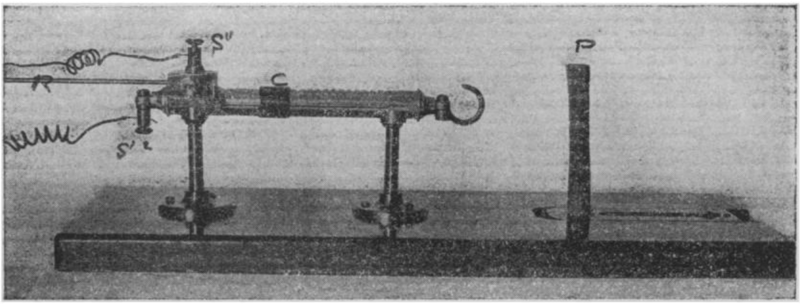

Fig. 1.

being connected with the index of the balance. In reacting, the reagent closes the hand around the post P.—adjusted to the proper distance from the 'trigger', and inserts the forefinger in the ring as far as the first joint. When the stimulus comes the reagent pulls the 'trigger', which breaks the contact between the rod R. and the scale index. The pull carries along the registering ring C. which is left in place at the forward end of the pull thus showing the force and extent of the reaction movement. If it is desired to change the initial tension of the spring, the rod R. can be pushed along the side of the scale and the spring set at any tension. In this way the influence of the initial tension on the reaction movement can be easily ascertained. Any anticipatory pull for 0 grams of tension is signalized by the failure of the chronoscope hands to move.

For the sake of comparison of the keys, pairs of series of reactions were taken with each of 10 reagents, each key being used in one series of a pair. The number of reactions in a series was 20, and one series in each pair was taken in halves with the other series sandwiched in between the halves to compensate possible practice effects. As the object of this experiment was merely to test the relative trustworthiness of the two keys, it will be sufficient to make a general statement of the results.

Although the reagents were inexperienced in reacting, the reaction times as well as the variations differed in no marked degree from those of experienced reagents with whom the processes of reaction had not passed over into the mechanical stage.

The figures showed the shorter reaction time for 7 of the 10 reagents with the telegraph key. If we were to 'guess' at the reason for this difference we should say it might in part, be due to the upward push of the key spring, and in part to the stronger tendency towards muscular reaction involved in

the reacting position for the telegraph key. With the trigger key, the hand and arm lie in a position producing less muscular strain than is the case with the Morse instrument, and no tension is required to hold in place the moving part of the instrument. Accordingly the content in consciousness of muscular strain is usually less for beginners with the trigger form of key and the reactions tend more to approach the sensory form.

The differences of proportional mean variation between the two keys were less marked than differences of reaction time and in general, so far as the data go, we should be inclined to say that taking merely the question of the time factor into account, the trigger key is as trustworthy an instrument as the old key.

Force and Extent of the Reaction Movement

So far no attention has been paid to the other factors of the reaction given by the trigger key, *i. e.*, to the factors of force and extent of pull. The object so far has been merely to compare the time data of the instruments, and with such *Versuchstiere* as beginners in psychology there is every incentive to keep the conditions of investigation as simple as possible.

The experiment that follows is a preliminary survey with one reagent of all the data given by the trigger key—the force and extent of the reaction movement in relation to each other and to the reaction time. The reagent for this purpose was Miss Shumate who had done much reacting both in the regular course of laboratory work and in investigations. Before coming to this work and during it, she had been using the telegraph key for reacting to light stimuli with variable signal. Under these conditions her reactions were of the sensory type. She had also taken part in the comparison experiment along with the unpracticed reagents, but had reacted eight periods instead of one. The results for seven of these periods (omitting the first where the data are imperfect) were:

	Tel. Key	Trig. Key
Reaction time—median of 7 series	257	225
Av. of m. v. of 7 series	26	22

A number of series was next taken with the trigger key set at different tensions from 0 grams to 1,000 grams—the reagent noting each time the extent, and consequently the force, of the reaction pull. The instructions to S. were simply to mark the condition of the tension—classing it as "high," "medium," or "low" and to note extent of pull. Reactions

which the reagent classed as of "low attention" are not included in results. The interval between signal and stimulus was varied slightly to prevent reactions from becoming mechanical. In response to inquiry, the reagent said that her motions were not influenced through noting their extent and force; in the process of reaction she had in mind chiefly the time factor with no thought of making the pulls uniform in extent.

About 40 reactions were taken each period, distributed in four series corresponding to four different tensions of the key. Under these regular conditions, with but slight interruption for introspections, the effects of practice became very noticeable, so that at the end of a month the reagent's average reaction time had decreased 75 to 100 sigma. Table II gives the figures for all the reactions of this experiment. Taking the April result, where practice effects practically disappeared, we find with this key, too, an increase in reaction time with increasing tension of the spring and along with this a tendency towards a decreasing absolute mean variation. With the weaker tensions the reactions were fairly mechanical; the reaction motion followed the stimulus without a conscious will impulse. With the higher tensions this was less the case, but whether with 1,000 grams, for example, each reaction motion was preceded by a deliberate impulse, or whether a general state, or 'set' of preparation for stronger impulses preceded the entire series, we do not yet know. In order to get mental conditions that were as far as possible constant, the introspections were reduced to a minimum. The tendency towards a smaller m. v. with the stronger tension indicates however, that the latter condition was the case.

To what is the increase in r. t. with increased tension due:— to the greater time required for the greater impulse or to the greater resistance to the movement of reaction? The indications from the table are that the latter is the case. The columns headed at^1, ap^1, at^2, ap^2, give the averages of the three quickest and the three slowest reaction-times respectively, together with the averages of the length (and strength) of pulls corresponding to these reactions. The table shows no agreement for any given resistance between length of reaction time and strength of pull[1]; of the 32 series tabulated, the quickest reactions give 16 longer and 14 shorter pulls than the slowest, while for 2 series within the limits of error of reading, the pulls are equal. In one of these series (10 reactions) the times ranged from 133 to 177 sigma, while the pulls were all of 1,775 grams; in the other, the time range was from 144 to 183,

[1]Curiously enough Ach (Willenstaetigkeit und Denken, S. 158) assumes that the opposite is true: *i. e.*, he regards it as "sicher" that the quicker reaction follows the stronger impulse.

TABLE II. TRIGGER-KEY

Reaction data of S for different tensions of spring

at¹ means average of ¼ of shortest reactions
at² means average of ¼ of longest reactions
ap¹ means average pulls for at¹
ap² means average pulls for at².

Grams tension	No. react.	Date	av. r. t.	m.v.	at¹	ap¹	at²	ap²	av. pull. m. m.
0 grams	11	Apr. 20	139	10	123	608	153	650	33
0 "	10	" 22	135	18	125	812	179	787	42
0 "	10	"' 25	143	11	129	767	158	742	41
0 "	9	" 27	132	9	116	800	145	782	41
0 "	11	" 29	154	24	124	717	169	733	38
av.			141	14					39
100 grams	9	Apr. 20	146	7	133	875	154	862	35
200 "	11	" 22	139	10	127	908	155	925	38
200 "	9	" 25	176	9	135	887	187	900	36
200 "	10	" 27	145	16	124	908	169	975	39
200 "	10	" 29	159	7	149	825	172	833	33
200 "	11	" 18	149	14	125	883	167	871	35
av.			152	10					36
300 grams	20	Mch. 2	190	17	167	955	207	960	34
300 "	17	" 14	172	9	162	955	185	860	32
400 grams	20	Mch. 16	185	15	163	970	209	1075	33
400 "	25	" 21	176	14	153	1075	211	1050	35
500 grams	19	Apr. 8	154	26	124	1070	198	1110	31
600 grams	10	Apr. 11	162	15	139	1200	184	1225	32
600 "	10	" 18	153	5	143	1250	160	1242	33
600 "	11	" 20	145	13	135	1167	173	1133	29
600	8	" 22	153	24	128	1275	184	1287	34
600 "	10	" 25	176	9	162	1208	189	1200	32
600 "	10	" 27	139	7	129	1283	147	1312	36
600 "	10	" 29	157	11	129	1175	147	1175	30
av.			155	12					32
800 grams	18	Mch. 23	177	24	148	1388	215	1360	30
800 "	20	Apr. 13	138	14	116	1370	161	1395	31
800 "	20	" 15	162	12	144	1435	185	1425	33
av.			159	17					31
1000 grams	10	Apr. 18	159	12	141	1567	171	1583	30
1000 "	11	" 20	163	14	145	1542	188	1525	28
1000 "	10	" 22	176	18	146	1566	203	1533	29
1000 "	9	" 25	169	8	158	1600	186	1550	29
1000 "	10	" 27	163	8	149	1600	173	1600	30
1000 "	10	" 29	171	9	157	1567	184	1575	30
av.			167	10					29

with a uniform pull of 1,600 grams. There is therefore here no proportion between the reaction-time and strength of motor impulse for any given resistance. In addition, the m. v. show no increase with increase in resistance; indeed there is, for this reagent, a slight tendency towards a decrease of this quantity. If the observed increase in reaction time with increased tension were due to increased time in the discharge of the motor impulse, there would probably be an increase in the resulting m. v.

The last column in Table II gives in millimeters the average distance pulled for the several tensions. The length of the reacting scale for 2,000 grams of weight is 105 millimeters. Consequently the distance pulled may be found from the formula $d = .0525\ (l\text{-}t)$ where l is the strength of the pull and t the initial tension at which the index was set. For this table l is taken as the average of ap^1 and ap^2 which is very close to the average pull for any tension, and in some cases coincides with it. The table indicates a tendency to decrease the distance pulled with increase in initial tension t the falling off amounting to about one centimeter in going from 0 grams initial tension to 1,000 grams. We have accordingly with increased tension of pull an increased reaction time with a tendency towards smaller mean variation and a decrease in distance pulled. As this article is merely a preliminary survey of the field with one reagent, any attempt to evaluate the results would be premature. It is hoped that experiments with additional reagents supplementing those already performed, will show that the trigger key is helpful in the investigation of reaction processes.